Energy Optimization in SAR Drone Missions Using Blockchain and Smart Contracts

Potential and Limitation

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Motivation

- SAR missions → drones explore hazardous/inaccessible areas.
- Challenge: Limited UAV battery life ⟶ short missions & high risk.
- Problem: Multi-agency coordination often fragmented → trust & accountability issues.

Research Gap

Existing work:

- Energy-aware scheduling (but weak on trust/accountability).
- Blockchain for coordination (but high latency).

Missing: A combined approach balancing efficiency + trust.

Our Contribution

A hybrid orchestration framework using:

- Blockchain → secure, tamper-proof mission records.
- Smart contracts → enforce energy-aware scheduling, logs, accountability.

Simulations validate trade-offs in energy, latency, and mission success.

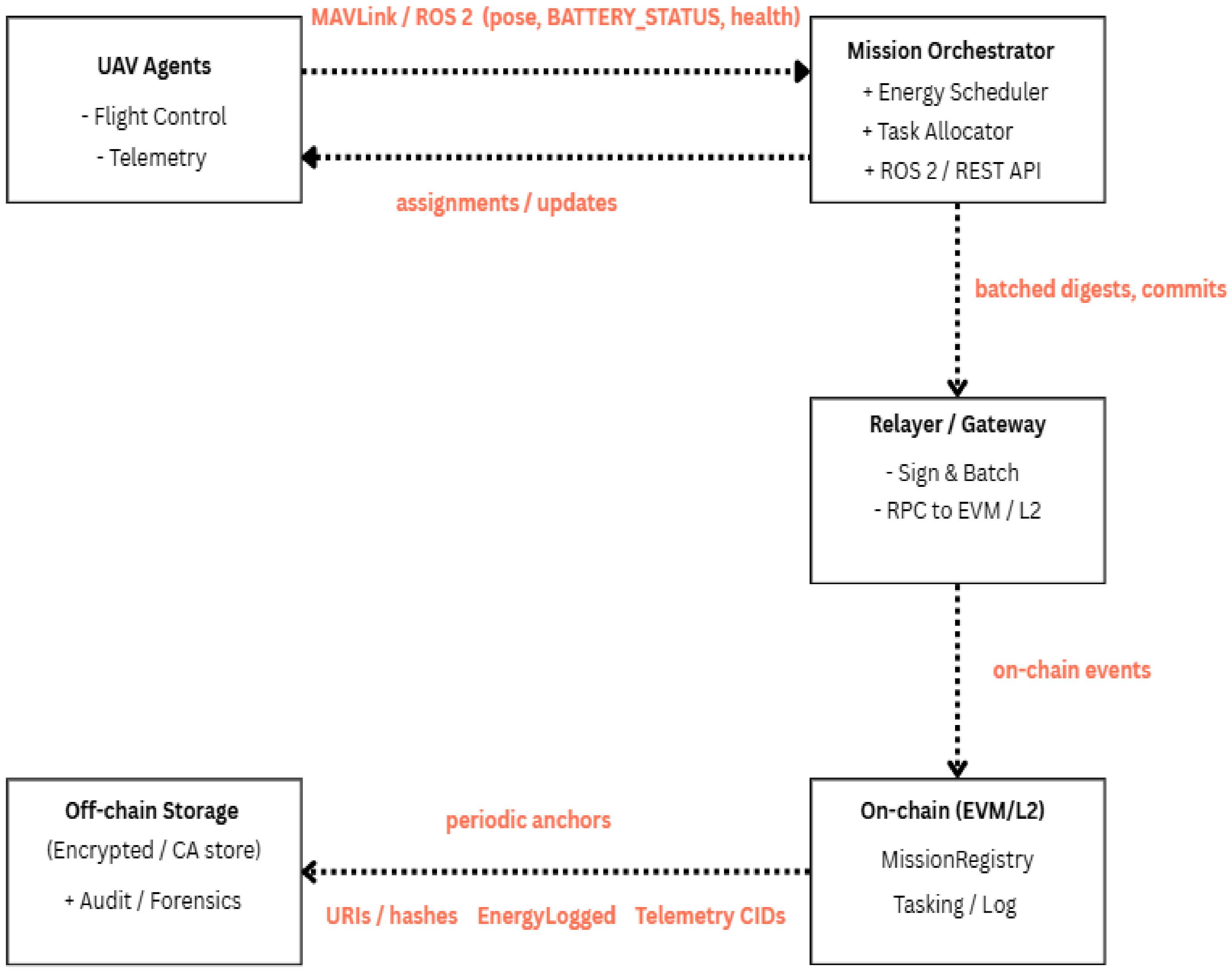
System Overview (High-Level)

Two-layer design:

- (L1) On-chain: Mission registry, commitments, energy checkpoints.
- (L2) Off-chain: Real-time scheduling, UAV control.

Goal:

Keep UAVs responsive without blockchain delays, while ensuring accountability



System Overview

Off-Chain Mission Control:

- UAVs send telemetry (position, SoC, velocity).
- Scheduler assigns tasks energy-efficiently in real time.
- Buffer + sync with blockchain if connectivity lost.

On-Chain Anchoring:

- Lightweight, tamper-proof records only:
  - Mission creation
  - Task commitments
  - Energy checkpoints
- Flexible pathways: Local DB, State Channels, L2 rollups, L1 blockchain.

Smart Contracts in SAR Missions & Energy Checkpointing

Roles: Mission Owner, Orchestrator, UAV, Blockchain.

Lifecycle: Mission creation → Task assignment → Energy logs → Mission closure.

UAV logs energy every Δt seconds or ΔWh consumed.

Records: timestamp, state of charge, energy delta.

Simulation Setup

- Tool: Python/SimPy discrete-event simulator.
- Scenario: 3×3 km area, 10 SAR tasks, 4 UAVs.
- UAVs modelled with different batteries, speeds, and power use.
- Tested anchoring modes: No chain, State Channels, L2, L1.

Results - Energy & Success

- Baseline (naive): ~120 Wh per mission, ~93% success
- Energy-aware scheduling: 16–20% less energy, ~97% success
- Blockchain anchoring preserved these gains (except L1 slower)

Results - Latency & Audit

- State channels (no chain): ~130 ms ⟶ near real-time
- L2 rollups: ~820 ms ⟶ responsive
- L1 blockchain: ~12.4 s ⟶ too slow for real-time, but strong audit
- Trade-off: responsiveness vs. auditability

Opportunities & Challenges

OPPORTUNITIES	CHALLENGES
Improves Trust and Transparency when missions involve multiple organizations.	High latency in L1
Incentives via smart contracts (e.g., energy-efficient task bonuses)	Weak connectivity in real SAR missions
Enhances interoperability through standardized events and roles.	Privacy (raw telemetry must stay off-chain)
Secure, auditable mission logs	Operational overhead (fees, key management, RPC reliability)

Conclusion & Future Work

- Hybrid system = efficiency + accountability
- Up to 20% energy savings and higher mission success
- Next steps:
  - Field trials with SAR partners
  - Permissioned blockchains for consortiums.
  - AI-driven scheduling, digital twins, edge computing.

Thank you!

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